An Examination of North Central Gulf Coast Cold Season Pre-Tornadic Vertical Wind Shear Environments since 1996

Jeffrey M. Medlin and Matthew Bunkers

NOAA-National Weather Service Forecast Office, Mobile, AL

NOAA-National Weather Service Forecast Office, Rapid City, SD

Introduction and Goals

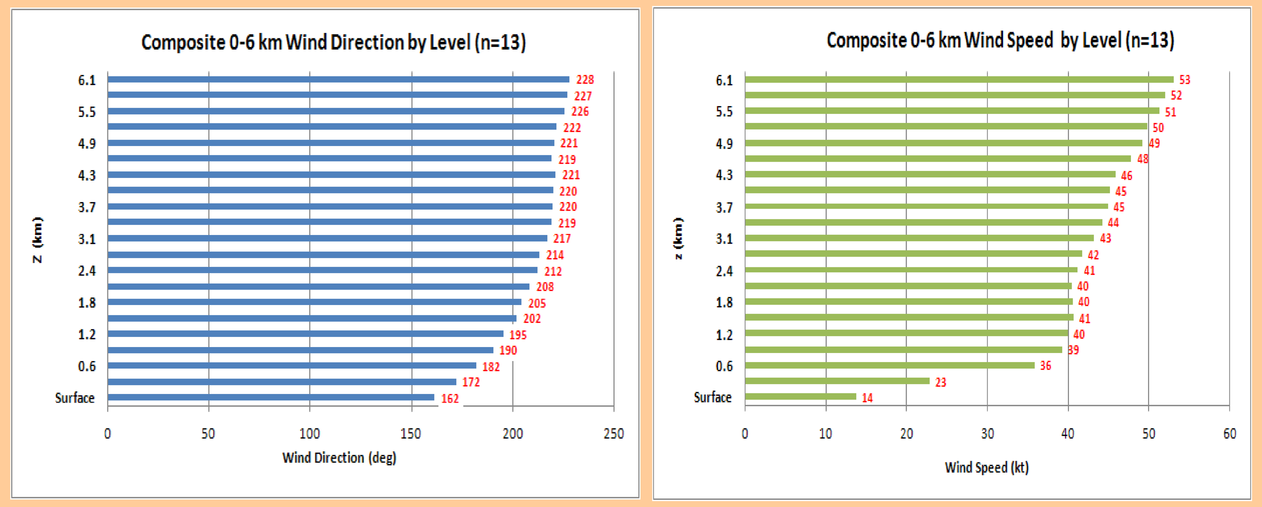
Using the KMOB WSR-88D Velocity Azimuth Display (VAD) winds for all cold-season (Oct-Apr) ≥F1 and ≥EF-1 tornado-producing mesocyclones occurring within 60 n mi, the purpose is to ***document and analyze*** ambient vertical wind shear characteristics immediately prior to tornado occurrence. Twenty-three tornado events, occurring on 14 days, were identified from Jan 1994–Oct 2007. Of these, 13 tornadoes, occurring on 11 separate days, were identified for detailed examination. Hodographs were constructed closest to the time of tornado occurrence using VAD winds every 305 m (1 kft) to a height of 6.1 km (~20 kft). Time-matched KMOB METAR observations were used for the surface wind. Of the initial 23 tornadoes mentioned above, (n=6, or 26%) were bow echoes and no hodographs constructed for these.

Thermodynamic instability, its vertical distribution, and proximity to the greatest layer vertical wind shear will be investigated later. Also, the predictive accuracy of the 'Bunkers ID Method' for forecasting supercell motion will be tested at a point when the data set becomes larger.

Initial Goals Include:

- Reproduction of mean vertical wind profile, and corresponding composite hodographs using ~1 kft (0.3 km) vertical resolution.
- Analysis of the resultant distribution of vertical wind shear, the properties of storm-relative flow as they relate to observed thunderstorm structure and the corresponding contribution to horizontal vorticity production from available vertical wind shear.
- Analysis of observed and predicted storm motions 12-15 minutes prior to tornado production.
- Determination of which layer contains the most storm-relative helicity and assessment of how results compare to others?

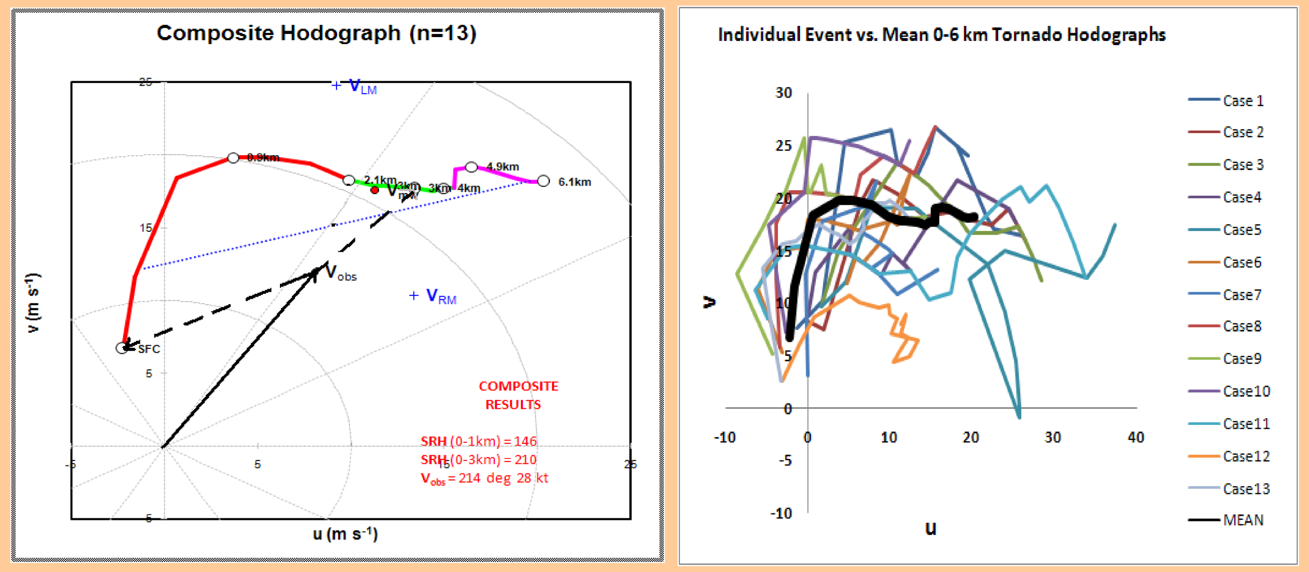
Results



a. b.

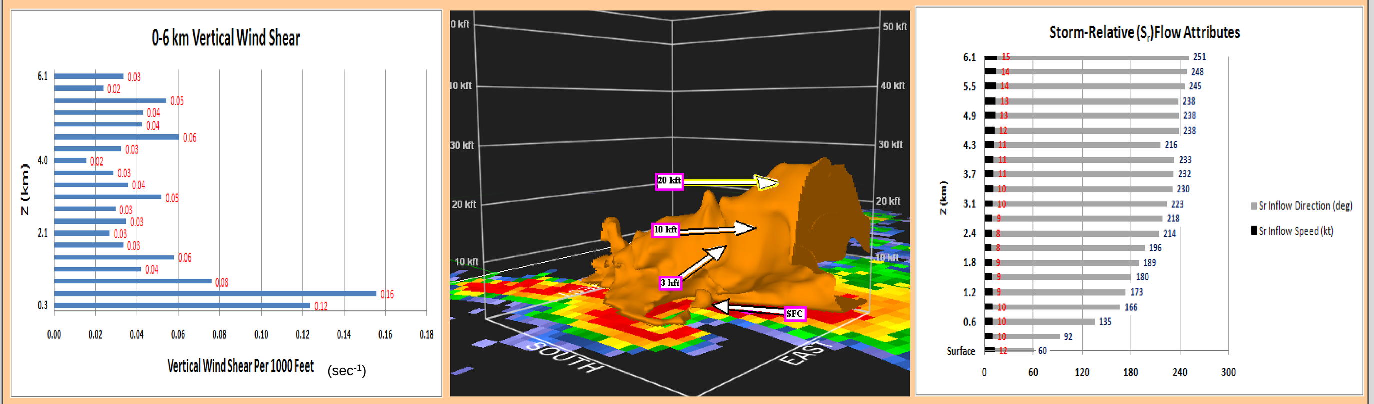
Fig. 1 – Composite of **(a)** mean 0-6 km wind direction (deg) and **(b)** mean 0-6 km wind speed (kt). Note backed boundary layer winds and a low-level jet centered around ~1.5 km. Also note that jet extends downward into a mechanically well-mixed boundary layer (~0.6 km).

Results



a. b.

Fig. 2 – **(a)** Composite 0-6 km hodograph using observed storm motion and **(b)** composite of all (n=13) hodographs. Note strongly clockwise curving shear vectors between the surface and 2 km with more of a straight-line orientation above. In **Fig 2b**., the mean hodograph is represented by the heavy black line.



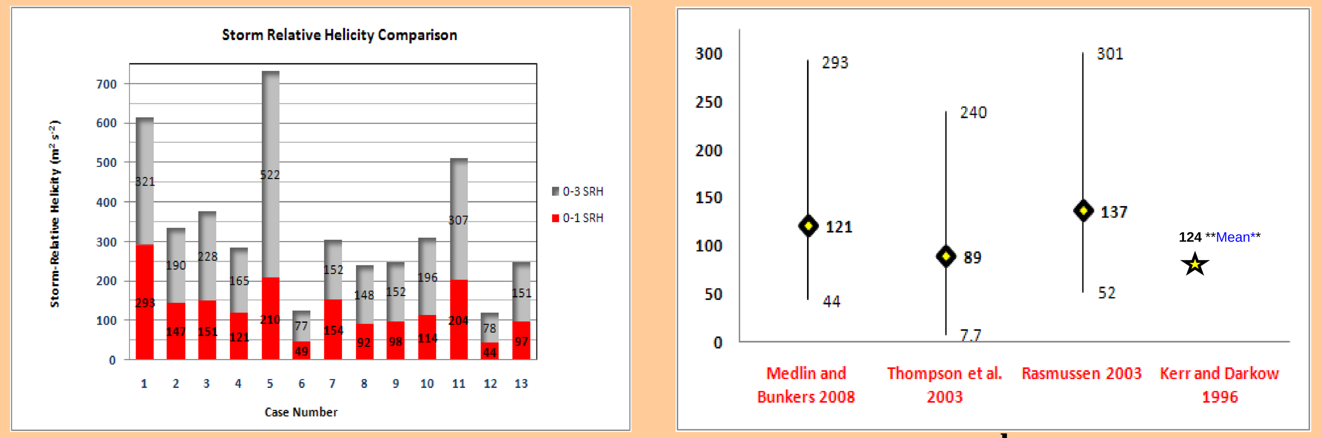
a. b. c.

Fig. 3 – Composite of **(a)** individual layer vertical wind shear (sec^{-1}) **(b)** a 3-D representation of a mesocyclone with typical representative dimensions near Gulfcrest, AL on 26 January 1995 annotated with storm-relative inflow vectors at the surface, 1.2-, 2.1-, 4.5- and 6 km levels and **(c)** 0-6 km storm-relative flow (deg, kt). The orange region in **Fig. 3b** represents a constant ≥48 dBZ radar reflectivity surface.

Observed Storm Motion

CASE	1	2	3	4	5	6	7	8	9	10	11	12	13	MEAN
DIR (deg)	231	232	225	253	252	174	210	187	171	188	252	211	190	**214**
Speed (kt)	33	35	30	23	25	28	33	27	27	33	33	16	20	**28**

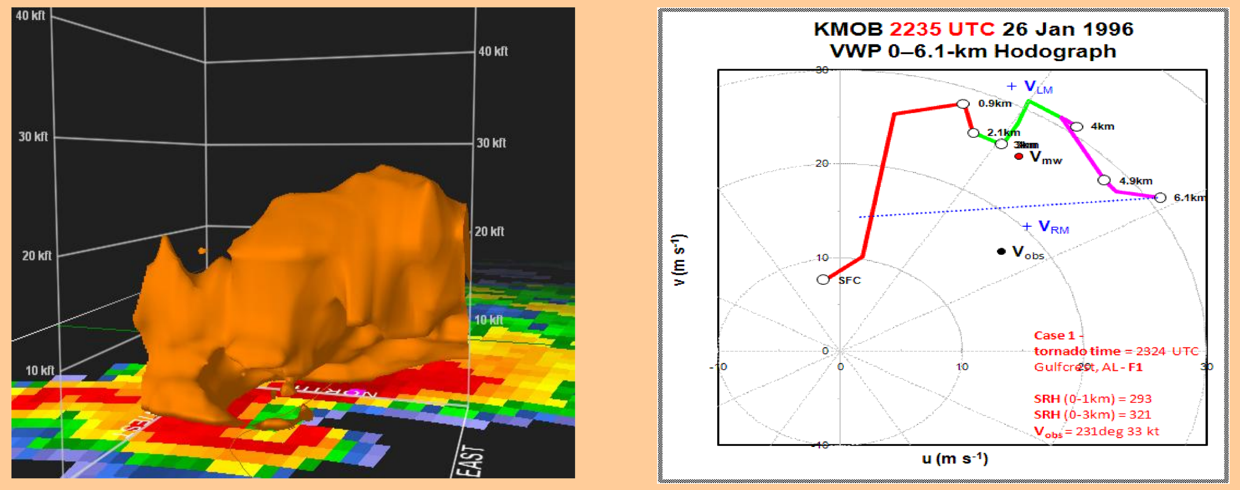
Fig. 4 – Observed storm motion vector for each case. Although not shown, when compared to both 0-3 and 0-6 km non density weighted mean layer winds (NDWMW), (5/13) events were to the right of (and ~30% slower) for the former while (9/13) events were to the right of (and ~19% slower) for the latter. Directional deviations where inconclusive for 0-6 km NDWMW. However for the 0-3 km NDWMW, a 10R90 initial prediction was solidly supported by the data.



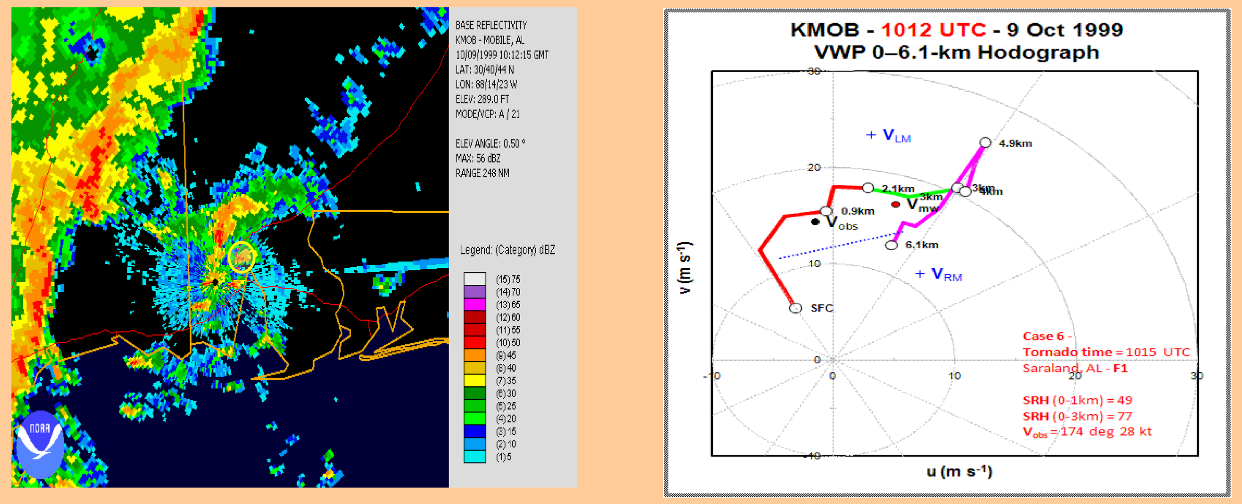
a. b.

Fig. 5 – **(a)** 0-3 km versus 0-1 km storm-relative helicity (SRH) comparison for each of the 13 cases and **(b)** a comparison of 0-1 km SRH study results to those of other studies. The median (yellow marker) and extrema are shown. The Kerr and Darkow (1996) median result was unavailable, however, the mean is displayed (yellow star).

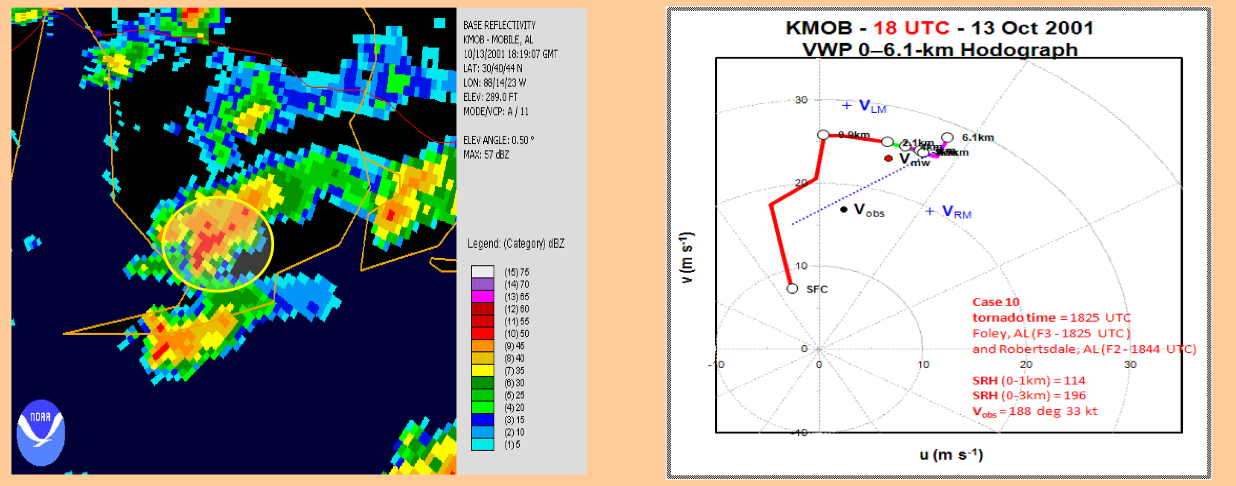
Individual Cases



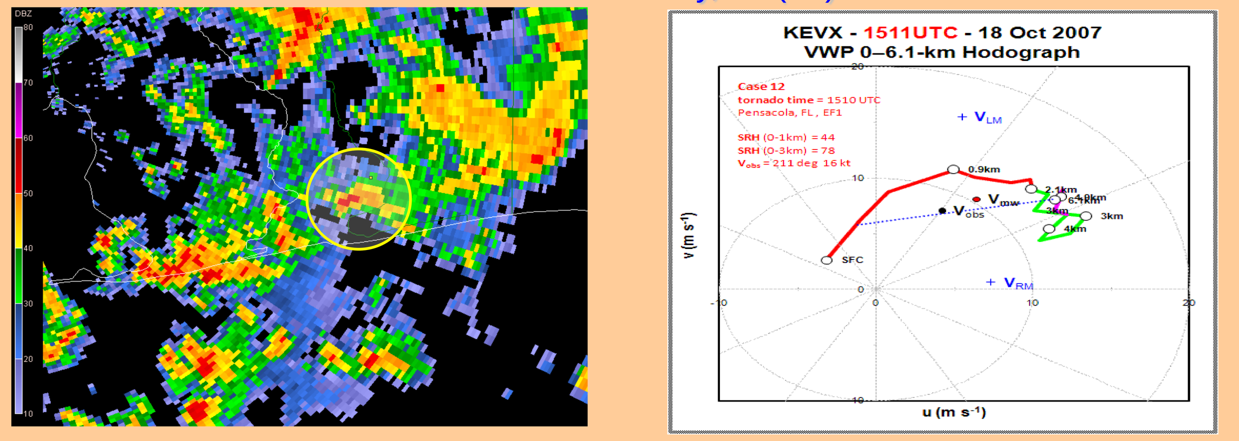
26 Jan 1996 – Gulfcrest, AL (F1)



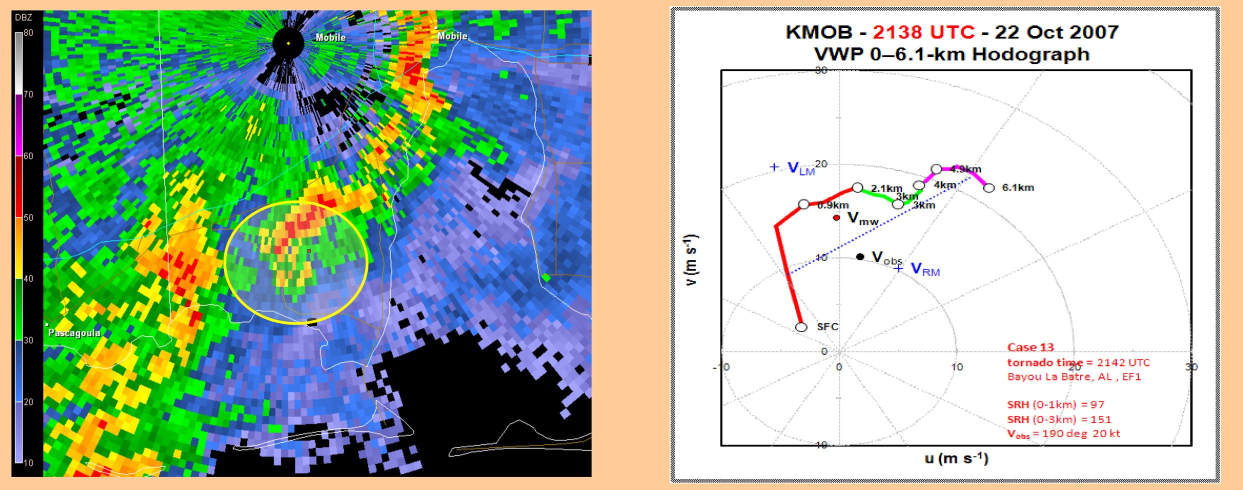
9 Oct 1999 – Saraland, AL (F1)



13 Oct 2001 – Foley, AL (F3)



18 Oct 2007 – Pensacola, FL (EF1)



22 Oct 1997 – Bayou La Batre, AL (EF-1)

Conclusions

- **Composite results reveal:**
  - Steadily veering wind profile through ~3.6 km.
  - Low-level jet (~22 m s^{-1}) centered near ~1.5 km.
  - Greatest vertical wind shear over lowest 600 m.
  - In a storm-relative reference frame, storm "sees" E->SE flow in low-levels – then eventual SW to W flow in mid- and upper updraft levels which provides a favorable precipitation downwind fallout pattern so as to promote updraft longevity.
- 0-6 km hodograph (n=13 cases) reveal strongly clockwise-curving shear vectors from sfc-2 km and more of a straight-line orientation above.
- 0-3 km ω_h is mostly streamwise – with 0-1 km SRH occupying ~68% of the total helical area! The latter finding supports the bulk of the total Sr-Helicity being distributed within the storm updraft inflow layer (consistent with other similar studies).
- During the 12-15 minute period prior to a tornado forming, deviant storm motion directions did not occur and thus did not play a role in increasing SRH given a constant vertical wind shear profile, but the tornado-producing mesocyclones definitely moved slower.
- When compared to both 0-3 and 0-6 km NDWMW, (5/13) cases moved to the right of and were ~30% slower for the former, while for the latter (9/13) cases moved to the right of and were ~19% slower. Directional deviations where inconclusive for 0-6 km.
- In a predictive storm motion sense, using a (10R80) of the 0-3 km NDWMW may yield the best possible 'first guess.' Of course the data set is limited at this point!
- It is also worth mention for each case identified, that only a few, and in most cases only one, warm sector tornado-producing mesocyclone resulted. However a much larger number of equally intense rotating mesocyclones occurred in association with each event and these did not produce tornadoes which lends itself to much deeper investigation.
- It is also interesting that 26% of n=23 tornadoes that occurred were associated with bow echoes! These were not considered in the present study.

References

- GR-Level II Analyst (used for some screen shots).
- Kerr B.W. and G.L. Darkow,, 1996: Storm-Relative Winds and Helicity in the Tornadic Thunderstorm Environment. *Wea Forecasting, 11,* 489–505.
- Markowsi P., C. Hannon, J. Frame, E. Lancaster, A. Pietrycha, R. Edwards, and R. L. Thompson, 2003: Characteristics of Vertical Wind Profiles near Supercells Obtained from the Rapid Update Cycle.*Wea. and Forecasting* ,1262–1272
- Rasmussen E. N., and D. O. Blanchard, 1998: A baseline climatology of sounding-derived supercell and tornado forecast parameters. *Wea. Forecasting*, 13, 1148–1164.
- Thompson R. L., R. Edwards, J. A. Hart, K. L. Elmore, and P. Markowski, 2003: Close proximity soundings within supercell environments obtained from the Rapid Update Cycle. *Wea. Forecasting*, 18, 1243–1261

For Further Information

NATIONAL WEATHER SERVICE Mobile - Pensacola

Please Contact: jeff.medlin@noaa.gov